Freshwater Inflows Methodology and Activities

Presented to the Texas Scientific Advisory Committee

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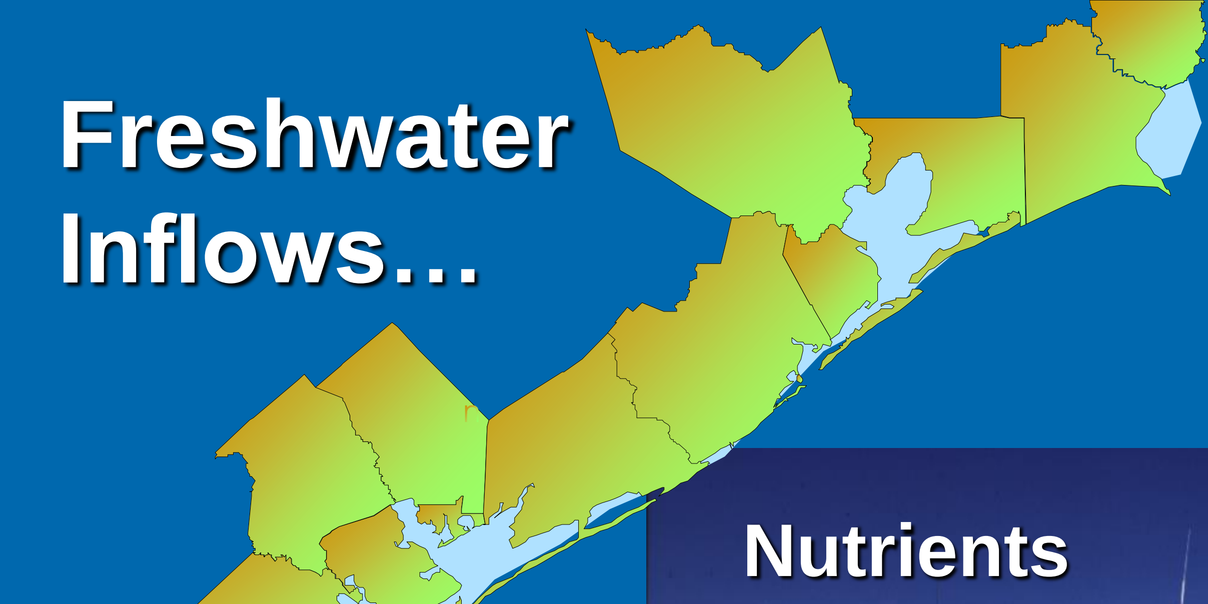
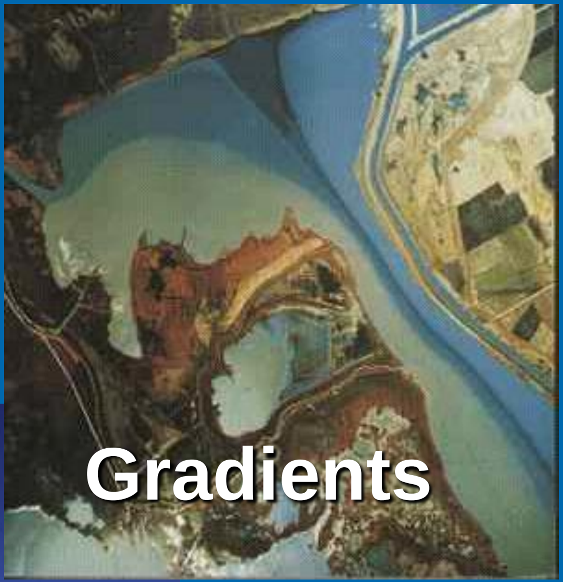
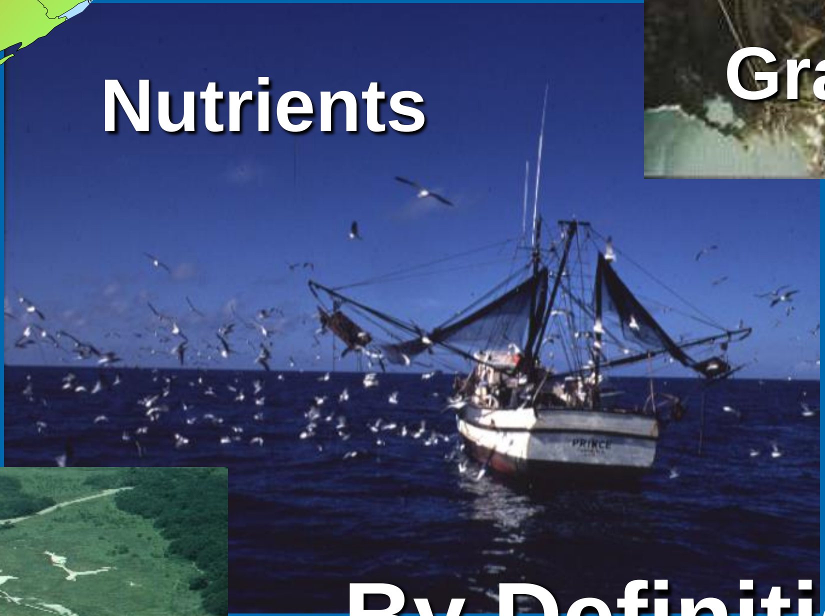
Introduction/Legislative Mandates

Freshwater Inflows…

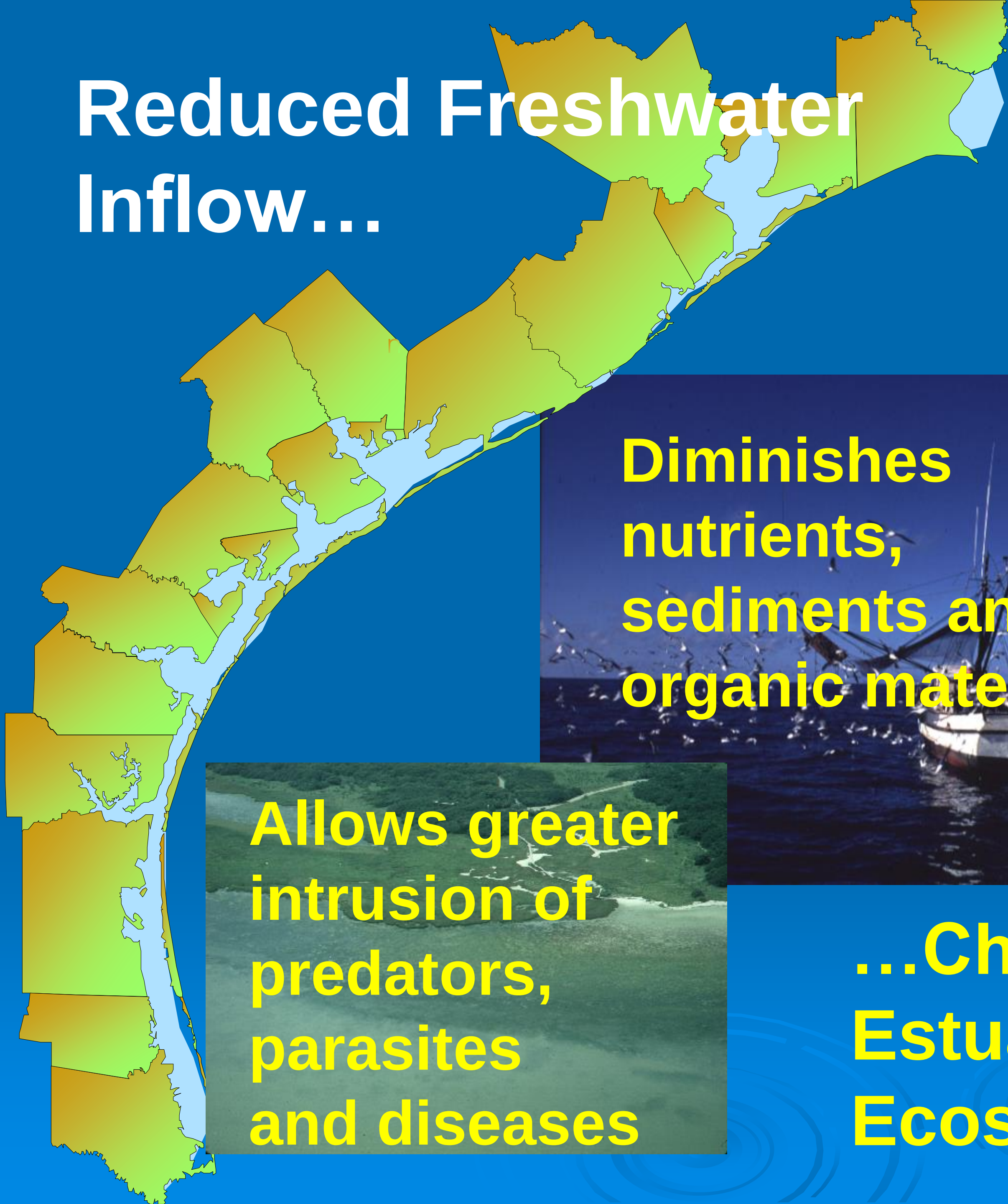


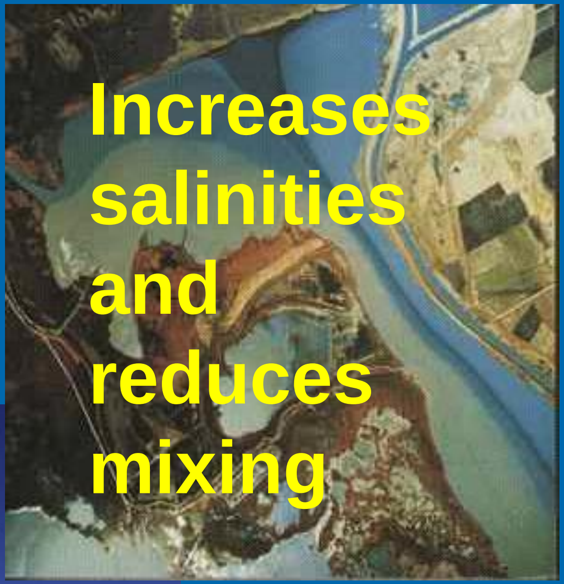




…By Definition Create and Sustain Estuaries

Reduced Freshwater Inflow…





Increases salinities and reduces mixing

Diminishes nutrients, sediments and organic material

Allows greater intrusion of predators, parasites and diseases

…Changes the Estuarine Ecosystem

Legal Basis for Bays and Estuaries Studies

- § 12.0011 Texas Parks and Wildlife Code
  Names TPWD as agency responsible for protection of fish and wildlife resources
- § 11.147 Texas Water Code
  Defines beneficial inflows
- § 16.058 Texas Water Code
  Requires TPWD to collect bays and estuaries data; conduct freshwater inflow studies.

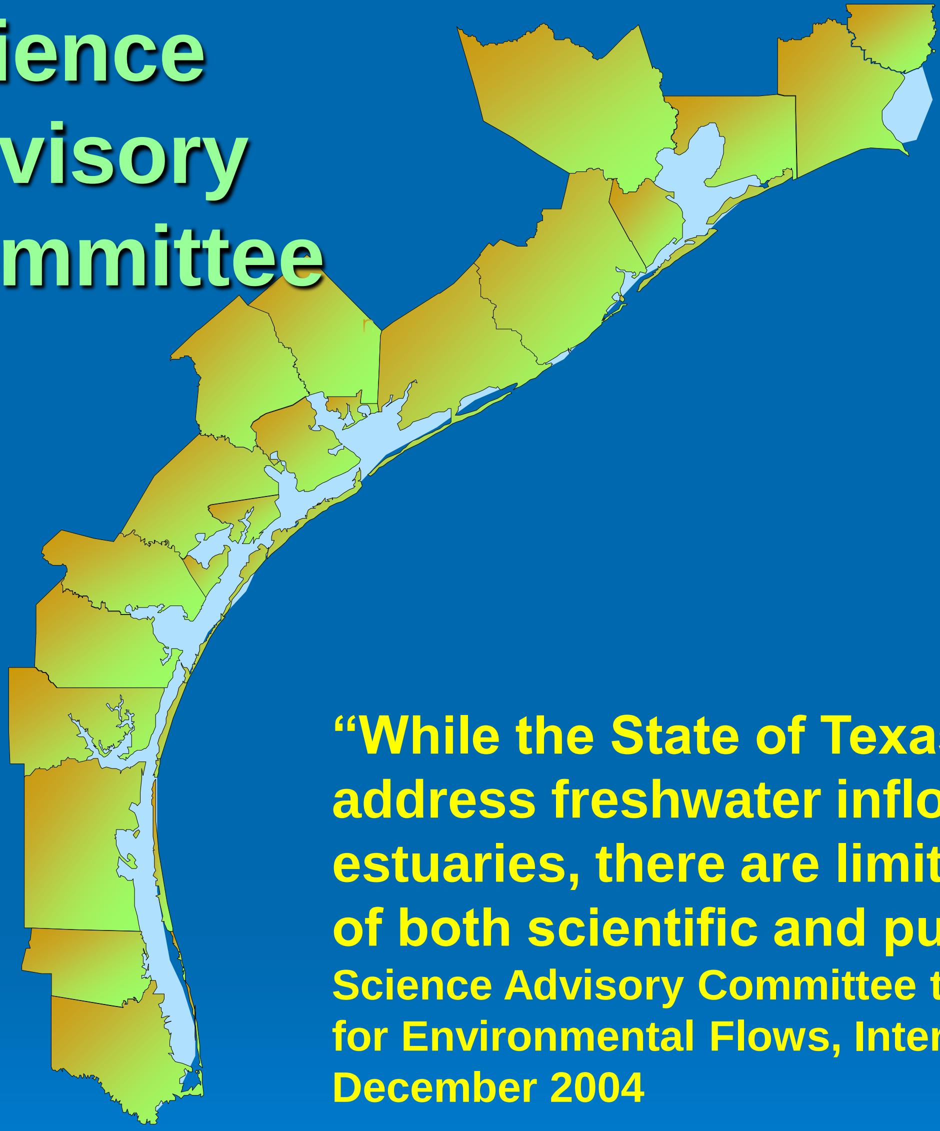
Texas Water Code Section 11.147

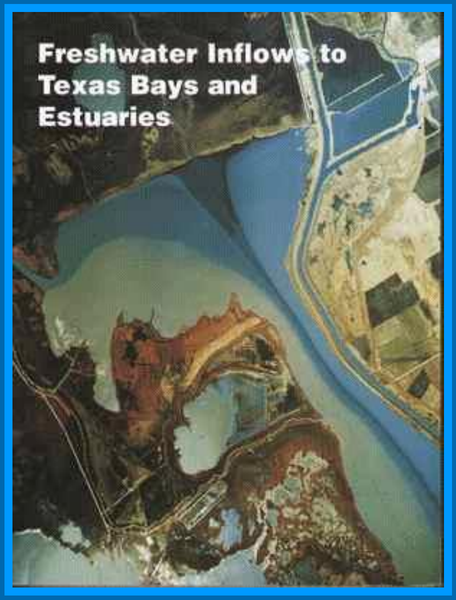
Defines *Beneficial Inflows* As the "<u>Salinity, Nutrient, and Sediment Loading Regime</u> Adequate to Maintain an Ecologically Sound Environment in the Receiving Bay and Estuary System That Is Necessary for the <u>Maintenance and Productivity of Economically Important and Ecologically Characteristic Sport or Commercial Fish and Shellfish Species</u> and Estuarine Life Upon Which Such Fish and Shellfish Are Dependent."

The Fundamental Scientific Basis of the Studies

The Fundamental Goal of the Recommendations

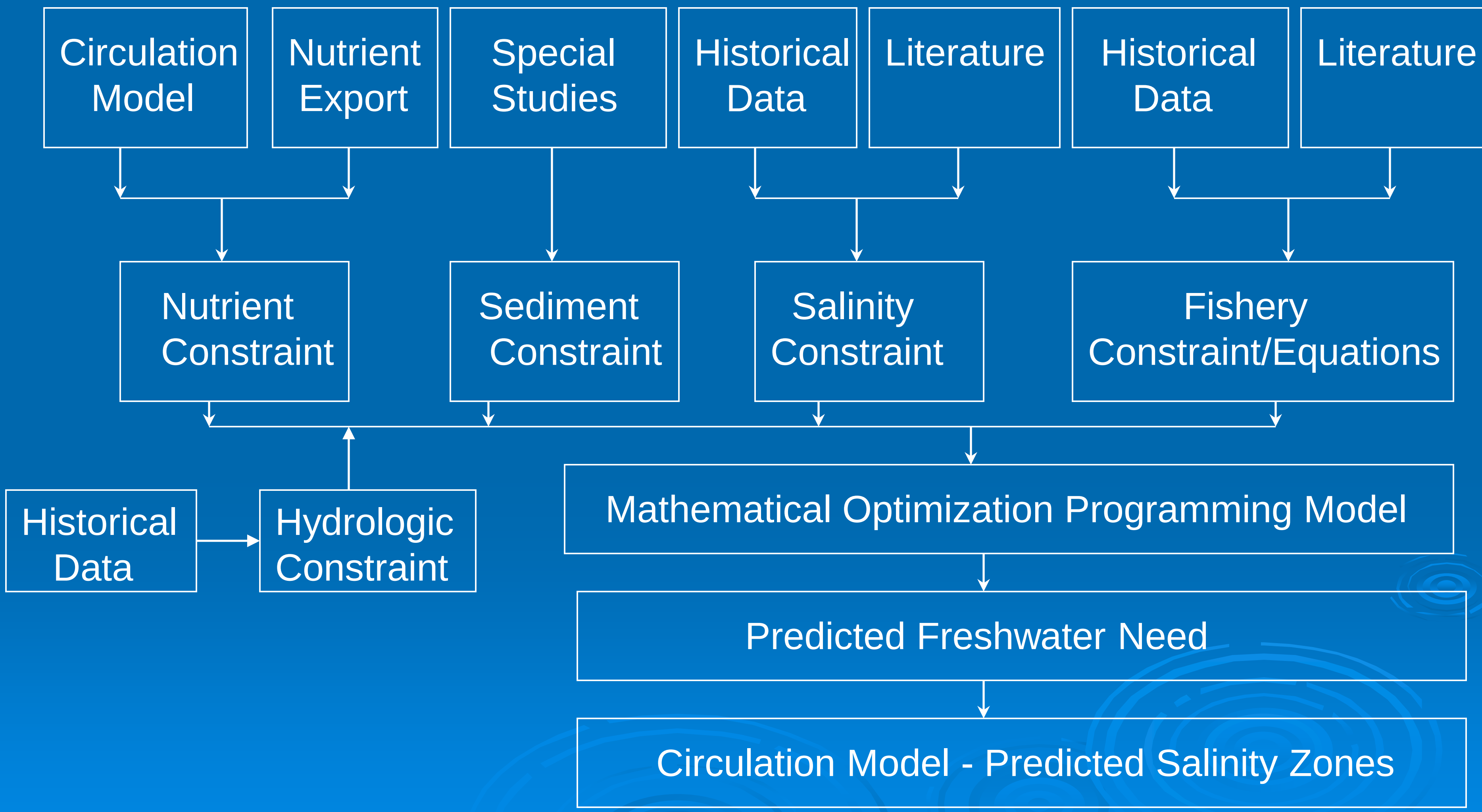
Science Advisory Committee



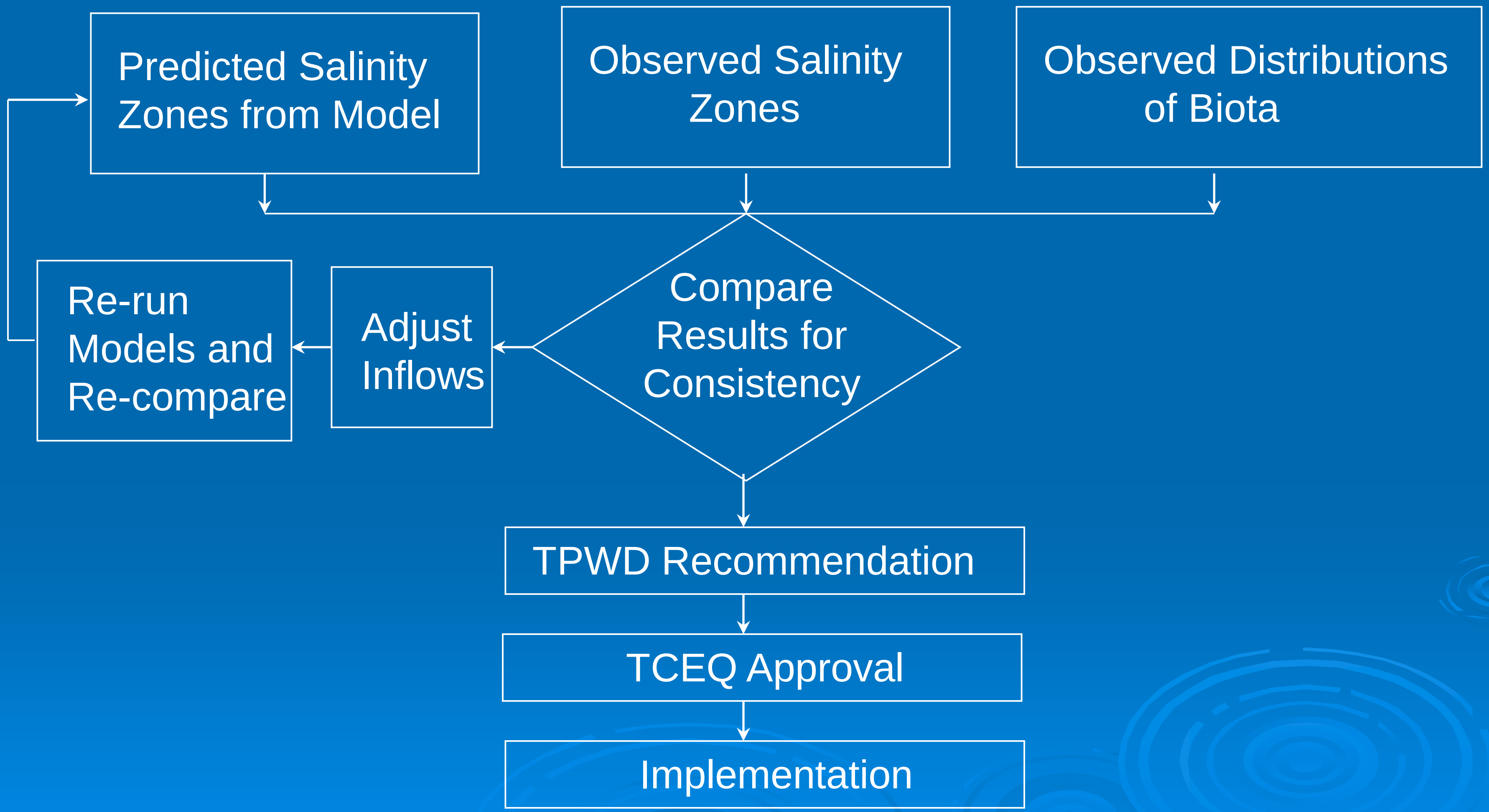


"While the State of Texas has pioneered tools to address freshwater inflow needs for bays and estuaries, there are limitations to these tools in light of both scientific and public policy evolution." –
Science Advisory Committee to the Study Commission on Water for Environmental Flows, Interim Report to the 79th Legislature, December 2004

Developing Inflow Recommendations



Recommending Inflows for a Healthy Estuary



B&E Methodology

Objectives

- Maintain commercial- and sport- fish and shellfish (75% - 85% of average historical harvest/abundance in the bays)
- Maintain habitat

Species Used in Analyses

	Estuary						
Species	Sabine-Neches	Trinity-San Jacinto	Lavaca-Colorado	Guadalupe	Mission-Aransas	Nueces	Laguna Madre
Brown Shrimp	X	X	X	X	X	X	X
White Shrimp	X	X	X	X	X	X	X
Blue Crab	X	X	X	X	X	X	X
Red Drum	X	X	X	X	X	X	X
Atlantic Croaker	X						
Gulf Menhaden	X		X				
Spot	X						
Spotted Seatrout	X	X		X		X	X
Eastern Oyster		X	X	X	X		
Black Drum		X		X	X	X	X
Southern Flounder		X			X	X	X
Striped Mullet			X				
Speckled Trout					X		
Pink Shrimp							X

What Affects Fisheries Productivity?

- Salinity
- Nutrients
- Sediment
- Habitat condition

→ Flow Dependent

But also ….

- Meteorology (temperature)
- Predator pressure
- Fishing pressure
- Disease
- Gulf conditions
- …

How Do You Put All This Together?

- Multiple complicated inputs relating flows to ecology
- Would also like to use water as efficiently as possible to achieve our goals (or put another way, we'd like to do as much as possible with the water we recommend for this purpose).
- Goal is to generate "freshwater inflow recommendations" – what does that mean?

One Approach

Mathematical optimization model

Why?

- Able to deal with multiple inputs (constraints)
- Able to easily evaluate multiple objectives
- Provides “optimum” solution (biggest bang for the buck)

TxEMP

- Texas Estuarine Mathematical Programming model (predecessor was Estuarine Linear Programming Model, Q. Martin, 1970’s-80’s)
- Multi-objective, stochastic constraints
- Solver (GRG2) developed by UT, L. Lasdon in 1980’s
- Customization to freshwater inflow needs problem by Y.K. Tung, Y. Bao, L. Mays in 1980’s

TxEMP Optimization Problem

- Objective function relates fisheries harvest/abundance to freshwater inflows
- Which fish? Brown shrimp, white shrimp, blue crab, eastern oyster, spotted seatrout, red drum, black drum, flounder, menhaden, and others
- Which flows? Monthly inflows

TxEMP Objective Function

Maximize ($\sum^{S}$ Hs) subject to constraints

where

Hs is harvest (abundance) for species S

TxEMP Constraints

- Salinity – Monthly salinity constraints based on species preferences (translated to flow constraints via salinity-flow regression equations)
- Nutrients – Global minimum flow value
- Sediment – Global minimum flow value

More TxEMP Constraints

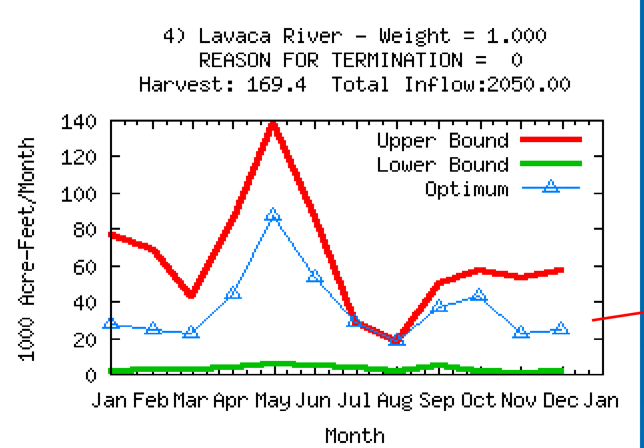
- Harvest – minimum 70%-80% of historical harvest/abundance
- Flow – Monthly median/mean flow upper bound, 10%'ile flow lower bound
- Flow – Seasonal and annual flows
- Harvest/Biomass Ratio – prevent one species dominating at expense of others

What Does TxEMP Do?

- Determine distribution of monthly inflows that maximize harvest/abundance achievable for within a small range of total annual flows subject to all constraints
- Change range of inflows for next calculation to generate response curve

Results

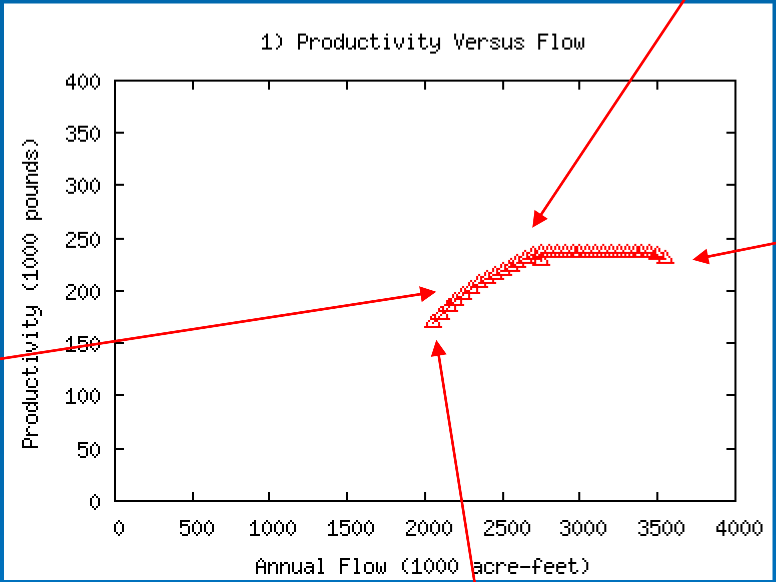
Monthly Flows



Response Curve

MaxH

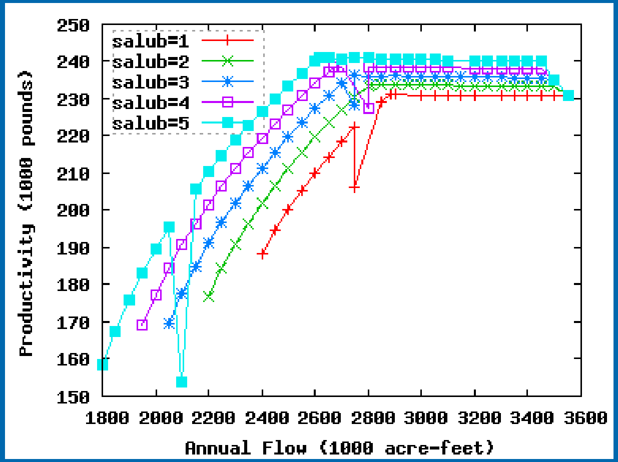
MaxQ



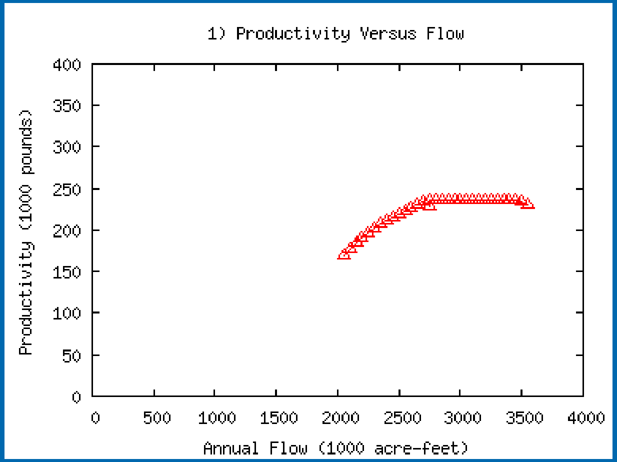
MinQ

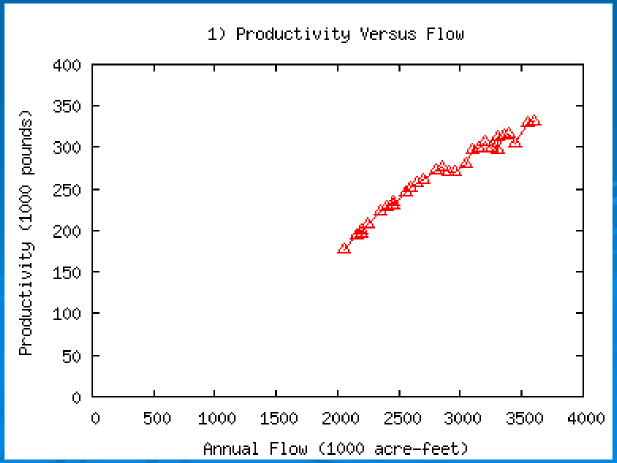
Model Application

Sensitivity Analyses



Unconstrained Solution





Summary of Optimization Model

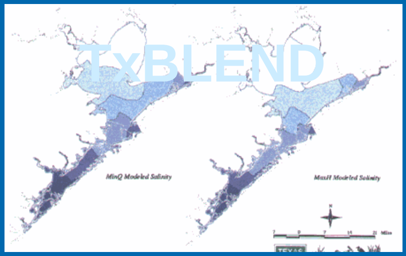
- Find monthly inflows that maximize harvest while meeting the hydrological and biological (and habitat) constraints

  (Aside ~= find minimum (most efficient) inflow that achieves target harvest)

- Judgment involved in selecting species, setting constraints – some constraints are “biological”, some are “management”

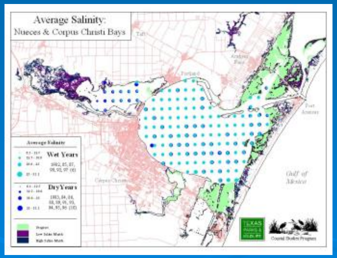
Checks on Solution

- TxBlend

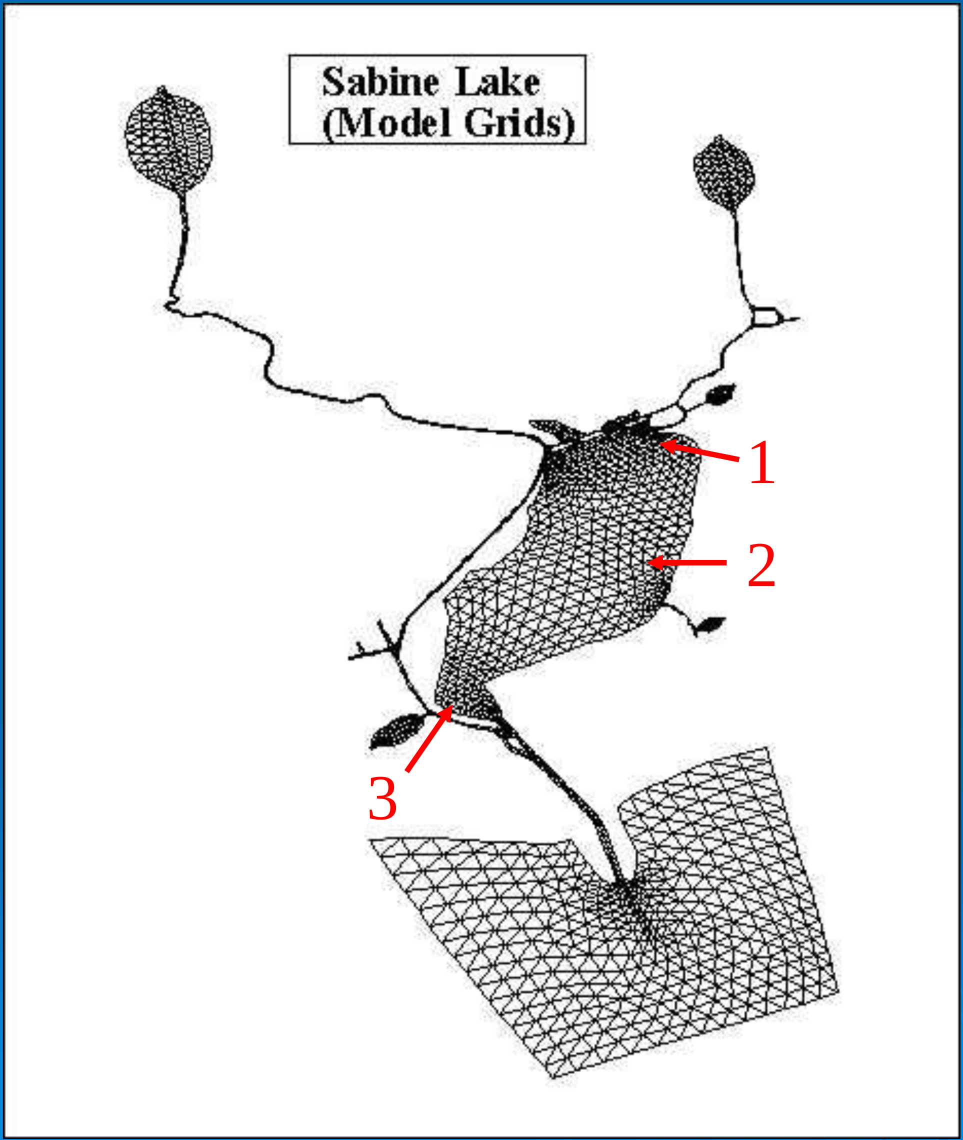


Hydrodynamic & Conservation Transport Model

- TPWD GIS/Habitat analyses

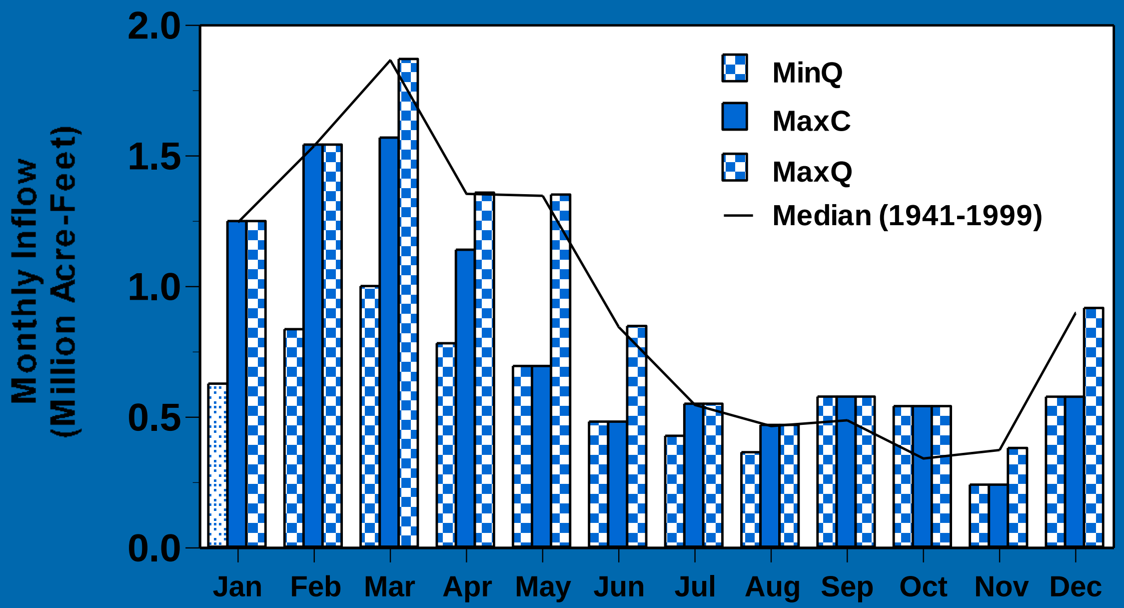


Sabine Lake "Final Check"

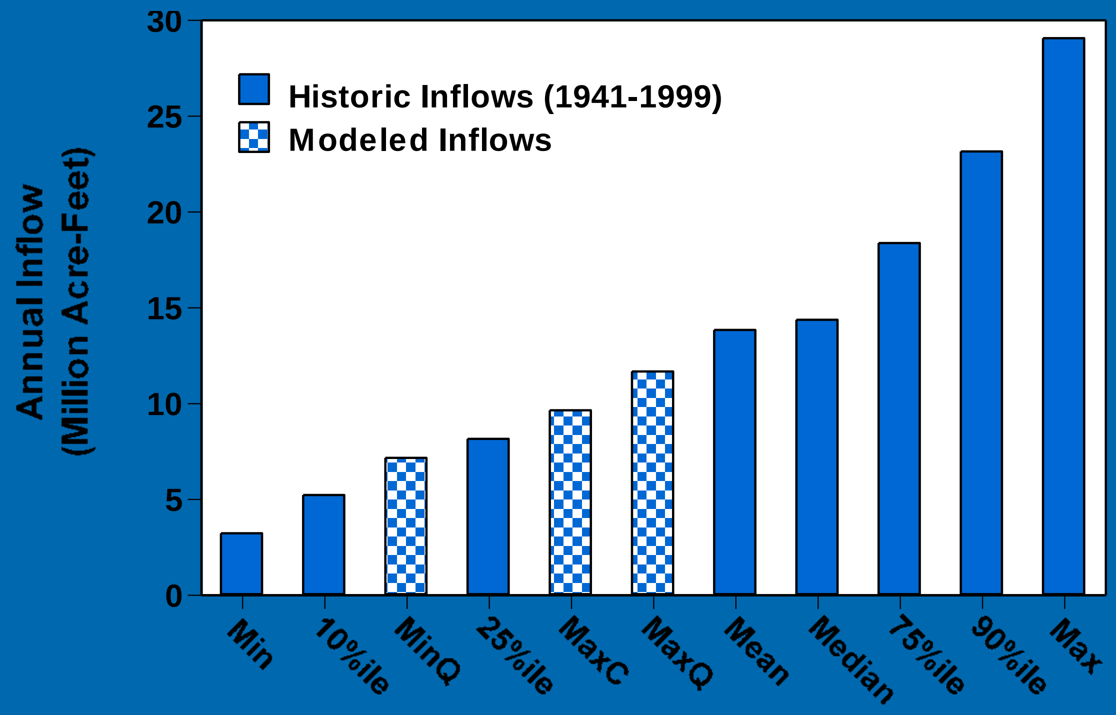


TPWD "checks" modeled salinities at 3 locations that represent important fisheries habitat within Sabine Lake

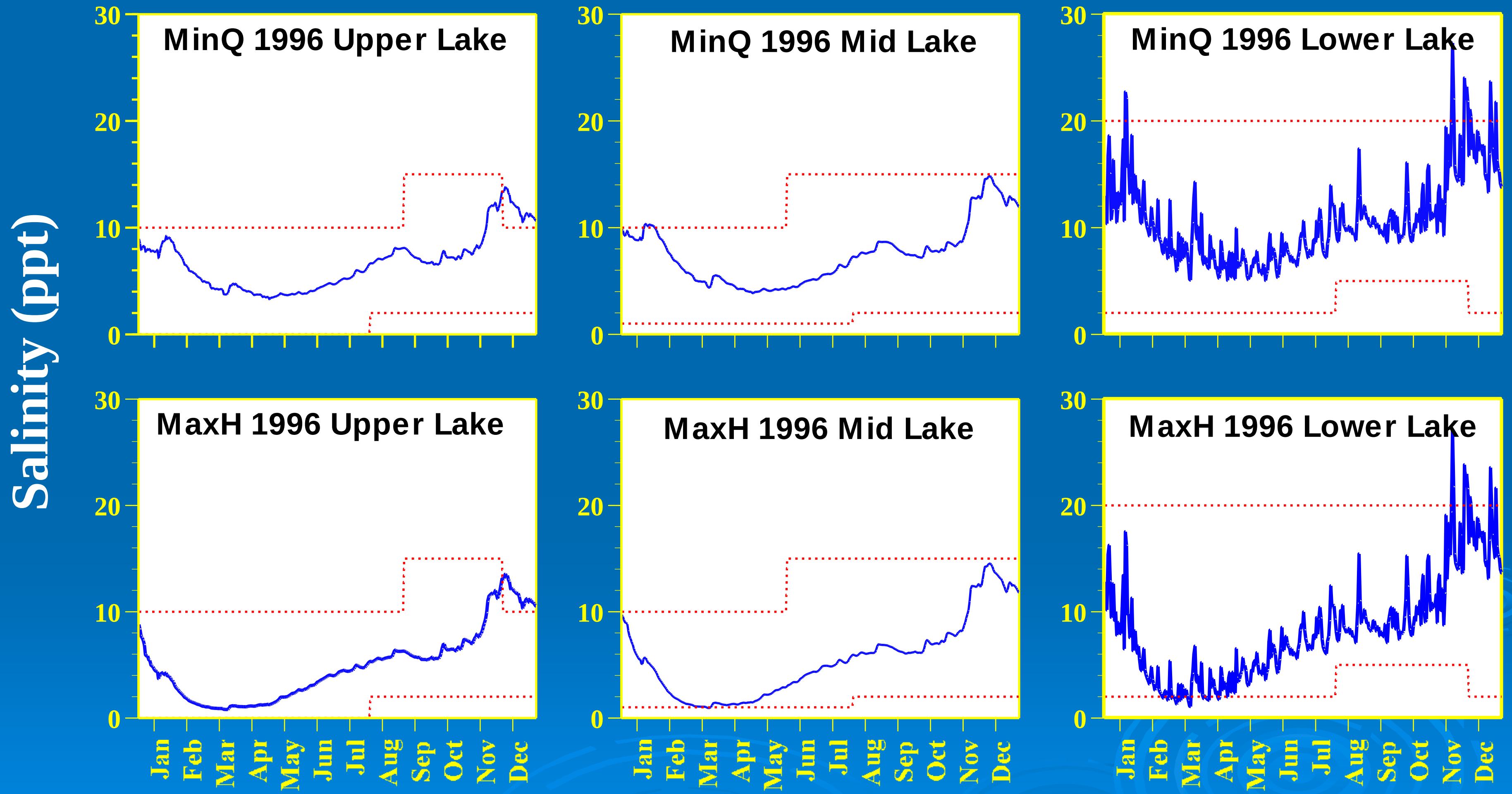
Sabine Lake Freshwater Inflow Recommendation



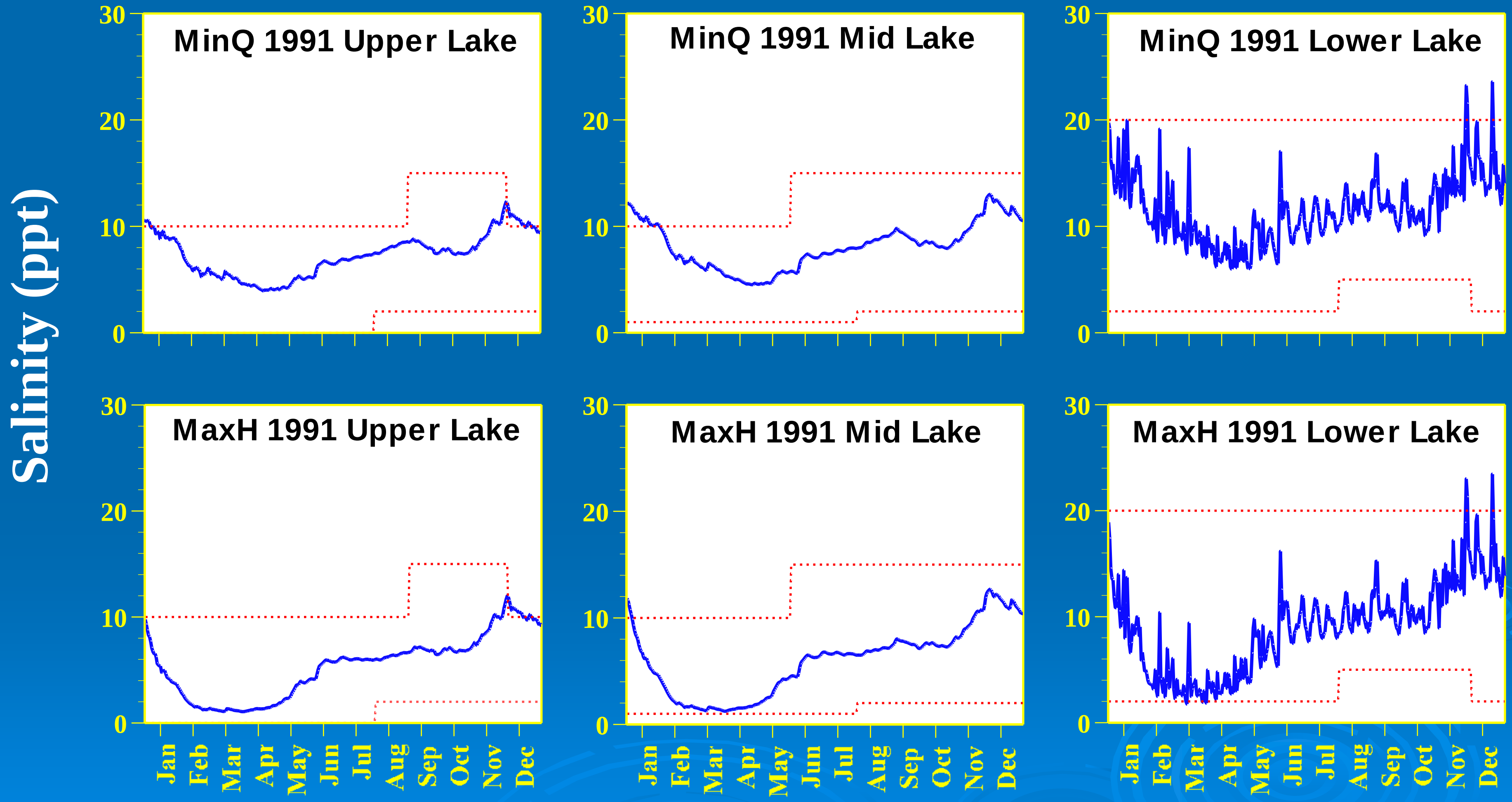
Modeled Inflows Compared to Historic Inflows

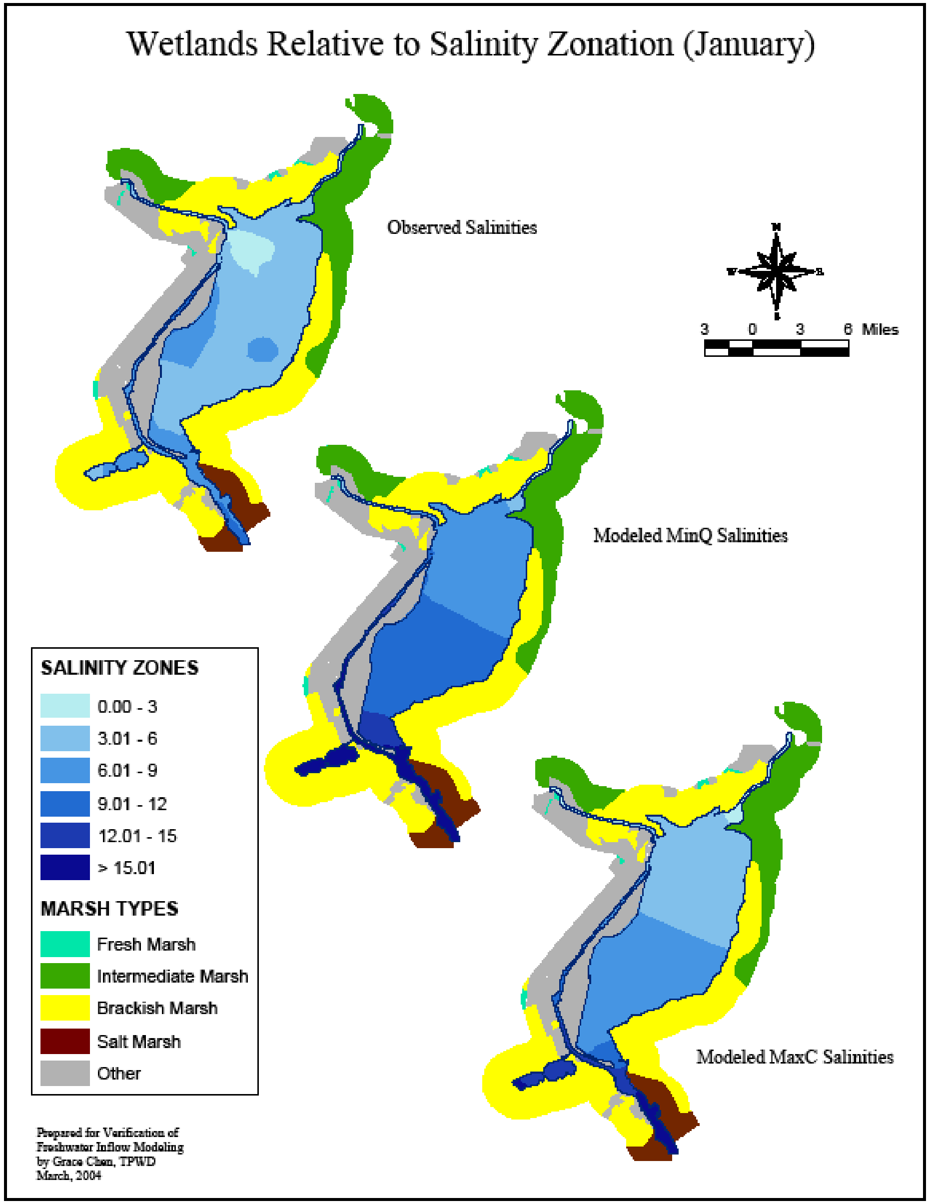


Salinity Exceedance - Dry Year



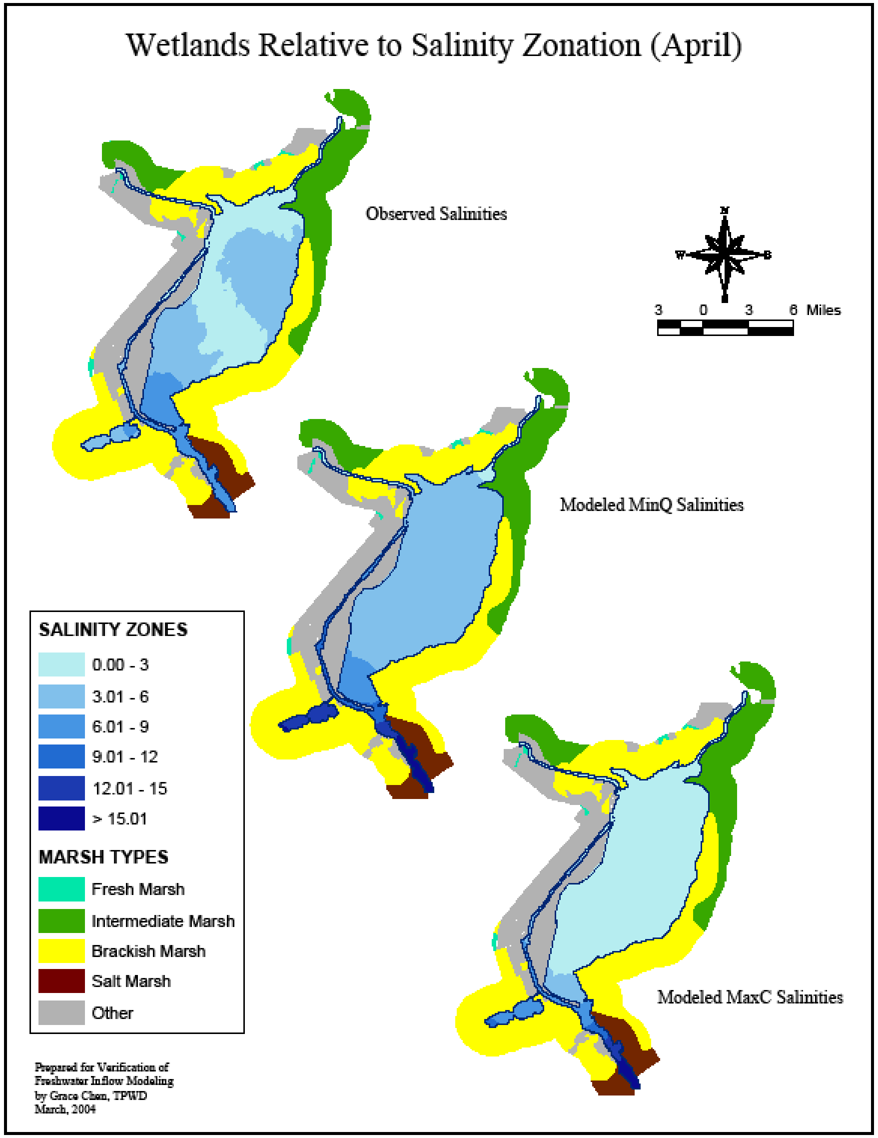
Salinity Exceedance - Wet Year





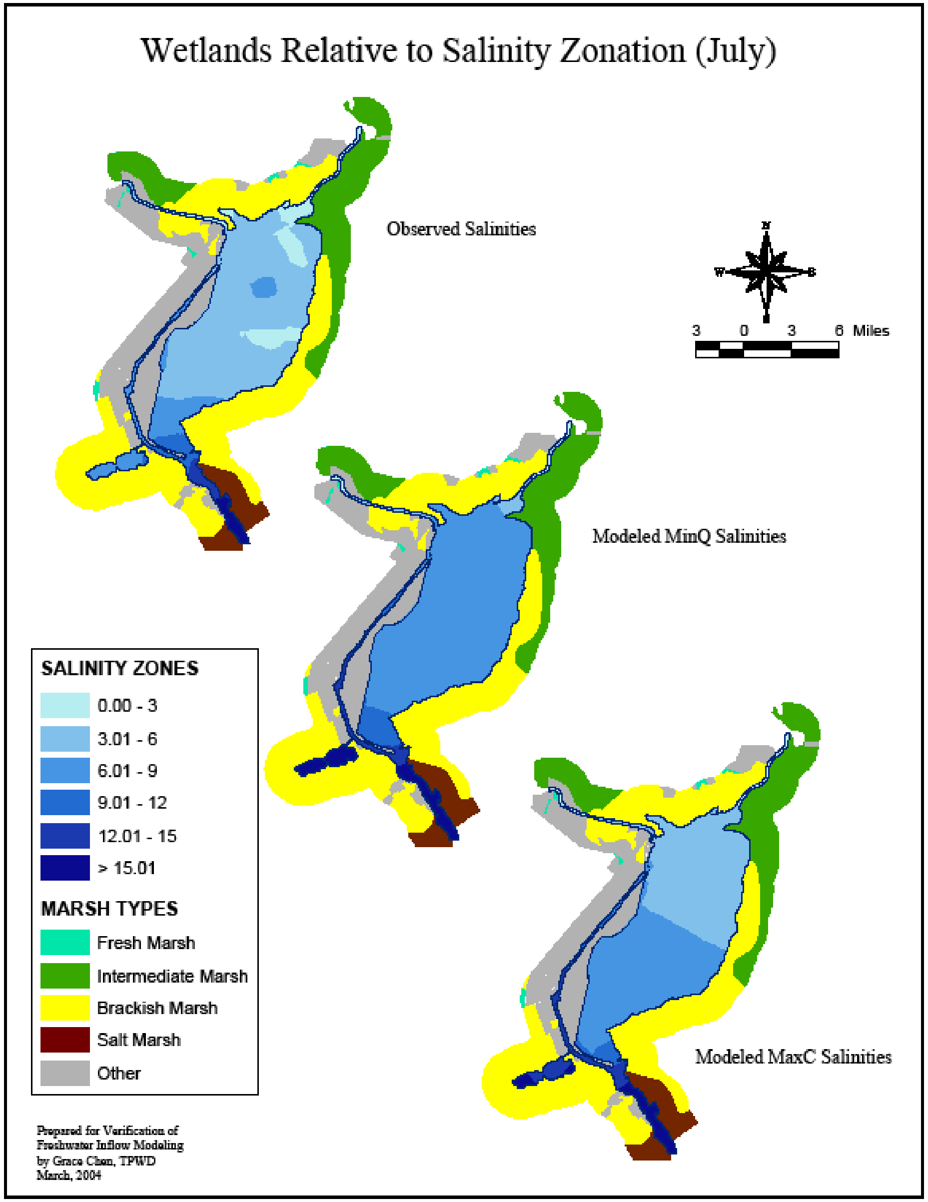
Comparison of observed and predicted salinities to habitat types

Winter



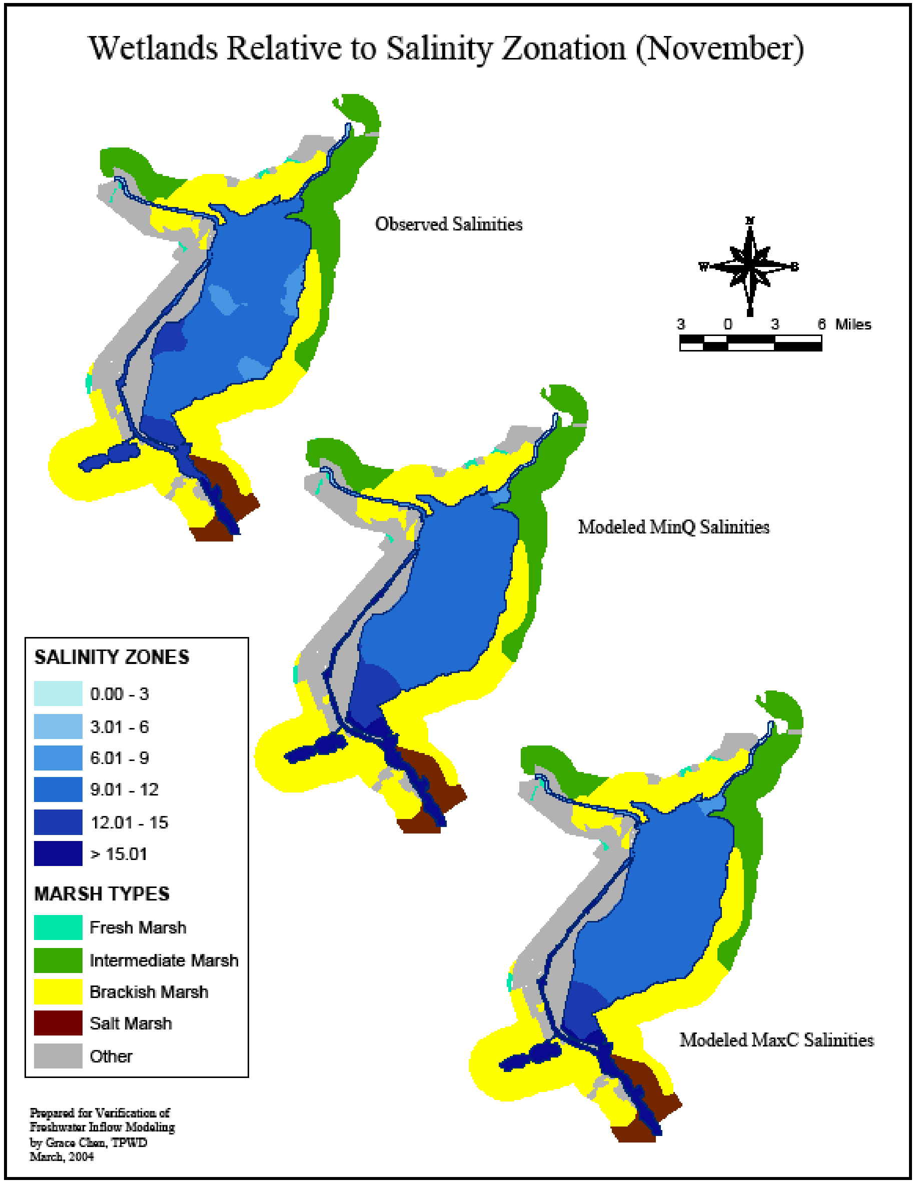
Comparison of observed and predicted salinities to habitat types

Spring



Comparison of observed and predicted salinities to habitat types

Summer



Comparison of observed and predicted salinities to habitat types

Fall

Application of Flow Recommendations in Permitting

Environmental Flows & Water Rights Permitting

"All the water that will ever be is, right now"

Section 11.147; TX Water Code

- When issuing a permit, the Commission MUST consider the effects of issuance on the bays and estuaries
- For permits issued within 200 river miles, the Commission SHALL include those conditions considered necessary to maintain beneficial inflows to any affected bay and estuary system
- One Factor considered: Sec. 16.058, TWC

Case Studies

- Lake Texana (Palmetto Bend)-Permit Amendment
- Choke Canyon-Commission Agreed Order
- LCRA-Water Management Plan
- Trinity/Galveston Bays-Regional Water Plan

Lake Texana

- Permit issued in 1972 w/ research provision (omitted in 1981 C of A)
- Certificate amended in 1985-to restore water for B&E research purposes
- LNRA, TWDB, TPWD & Sierra Club study
- Permit amended in 1994 to include a 2-tiered approach based on reservoir storage and inflows to the reservoir

Choke Canyon/Lake Corpus Christi Reservoir System

- Permit issued in 1976-w/Special Condition 5.B.
- Technical Advisory Comm. Created in 1990
- Nueces Estuary Advisory Council established in 1992
- Final Agreed Order issued in 1995
- FW inflow targets based on partial application of B&E studies using Max H and Min Q, as well as drought contingency flows

LCRA Water Management Plan

- Final judgment and decree-1988 requiring a water management plan
- LCRA/TPWD MOU to assess environmental flow conditions
- Interim environmental flows established
- Final report recommended two levels of environmental flows: Target & Critical

Trinity/Galveston Bays-Regional Water Plan

- GBFIG established in 1996 to promote dialogue on environmental flows
- In 2001, TPWD published FW inflow recommendations for estuary
- Target inflows w/in range of Min Q and Max H, Min Q-Sal, and Min-Historic
- Also included Target Minimum Frequencies

Questions – Discussion

Advantages/Strengths

- Easily understood objectives
- Sensible way to integrate a wide variety of information
- In principle makes best use of resource
- Constraints keep solution “reasonable”
- Makes use of available data/models
- Optimization model is objective

Issues/Weaknesses

- Data Issues
  - Harvest data
  - TPWD data
- Optimization relies on adequacy of harvest equations
- Choice of species
- Implementation of flows difficult
- Does not directly address low flow needs

Issues/Weaknesses

- Equations have relatively low r^2
- (Over)simplification of complex system
- Constraints
- Integration with Instream Flows
- Large focus on fisheries
- Response to non-optimal flows not clear
- Uncertainty in solution
- Amenability of problem to optimization

Ongoing Work

- Goals
  - monitor
  - quantitatively relate estuarine ecology to inflows
- Reanalysis of Galveston Bay results
- Model improvements/development (hydrology/hydrodynamics)
- Monitoring
- Analysis of WAMS scenarios
- New field methods (sidescan sonar, …)
- New modeling efforts (oyster larval transport, …)

Questions?

Simple Optimization Example

Find maximum value of f(x) (objective function, independent variable x)

such that

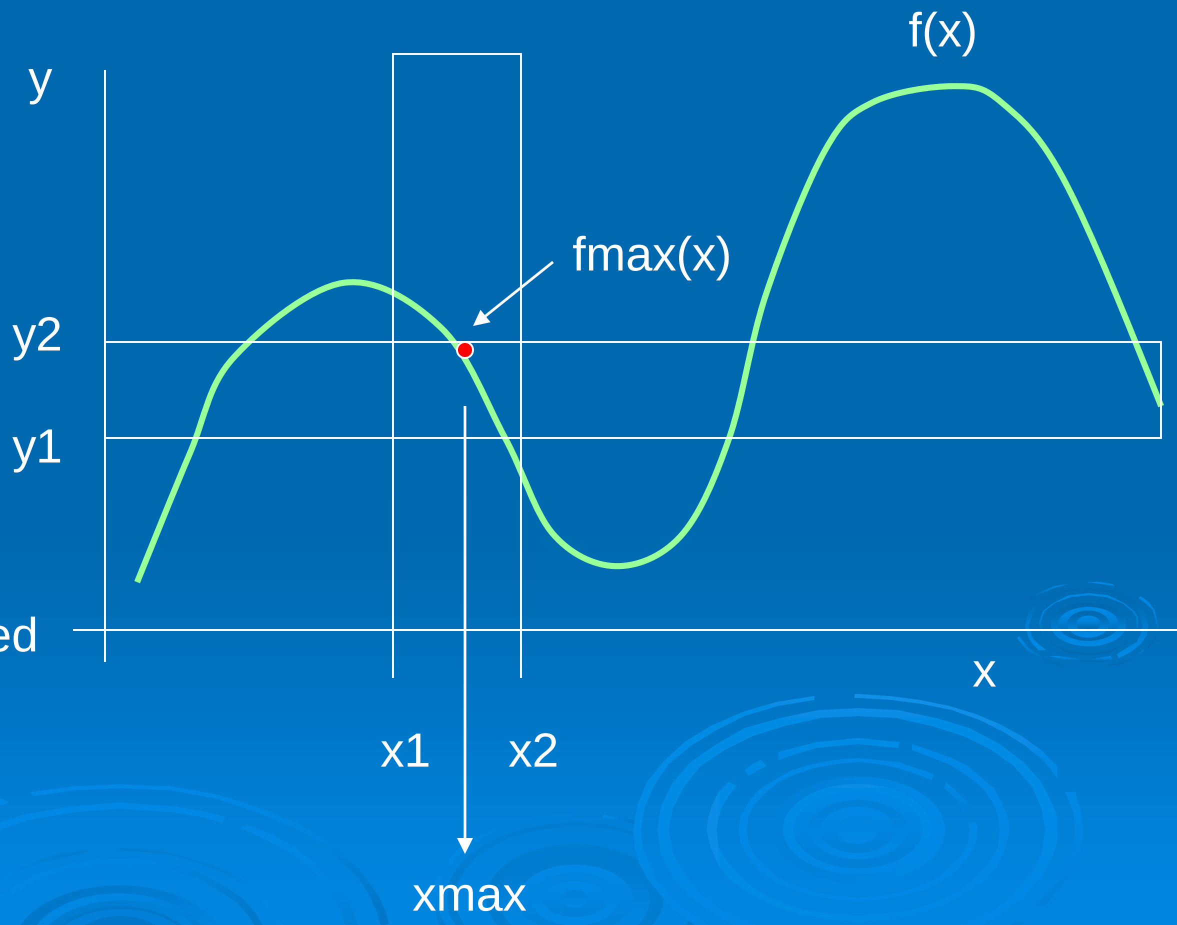
x1< x < x2 (constraint 1)

and

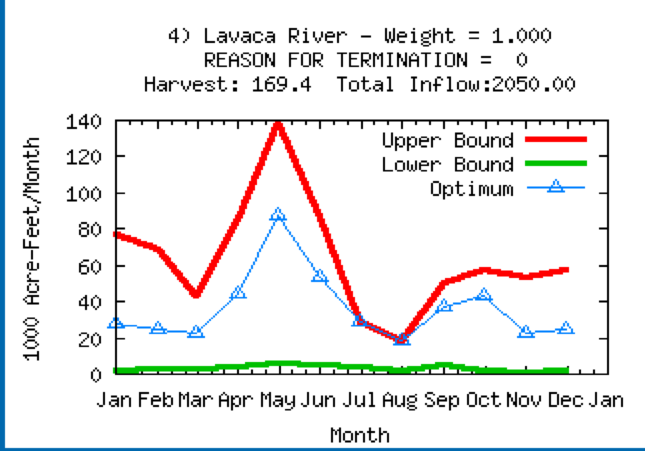
y1 < f(x) < y2 (constraint 2)

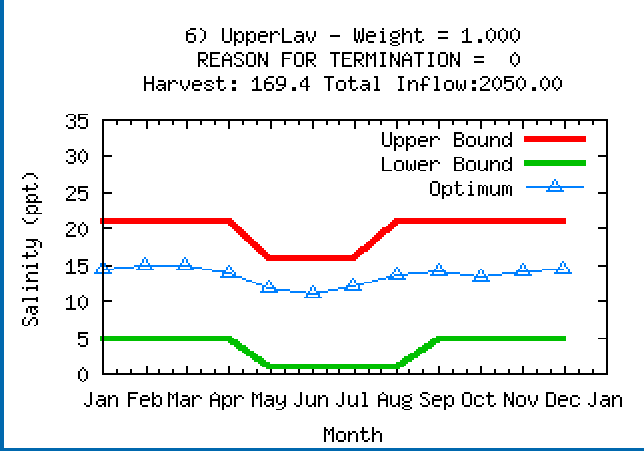
Answer provided by optimization model is value fmax(x) at x=xmax

Note that the solution is constrained In this case by the y2 constraint.

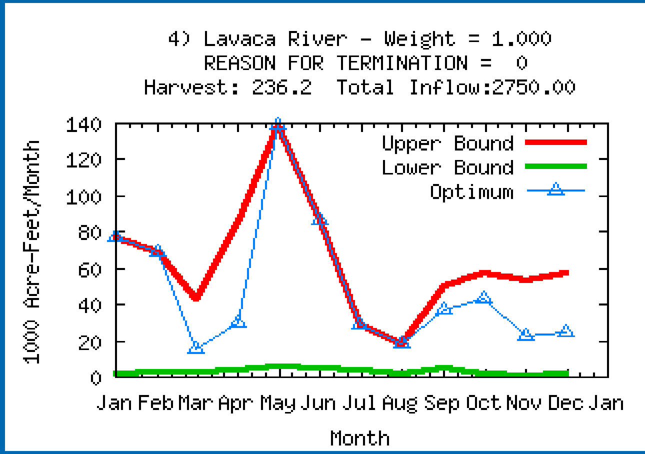


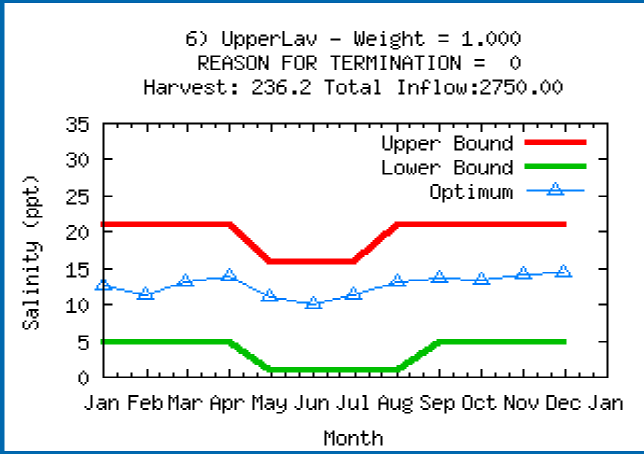
Qa=2050 Kaf
Harvest = 169.4 Klb





Qa=2750 Kaf
Harvest = 236.2 Klb





Qa=3550 Kaf
Harvest = 230.8 Klb